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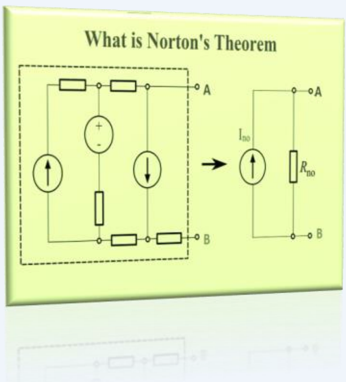
Electric Circuits



Unit: 4 | Lecture: 22

Circuit Theorems: Norton's Theorem

Dr. Hazem Falah Sakeek
Al-Azhar University of Gaza

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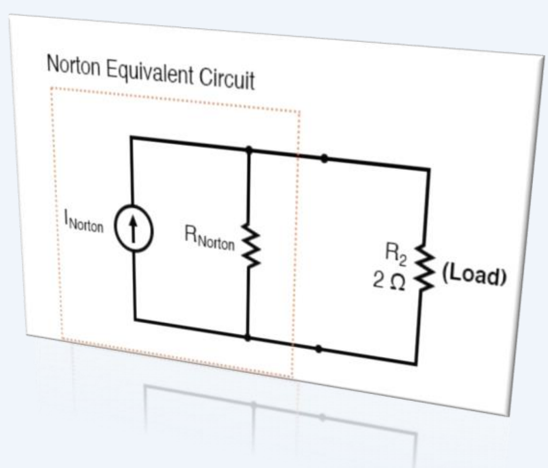
Circuit Theorems

4.1 Introduction
4.2 Linearity Property
4.3 Superposition
4.4 Source Transformation
4.5 Thevenin's Theorem
4.6 Norton's Theorem
4.7 Maximum Power Transfer



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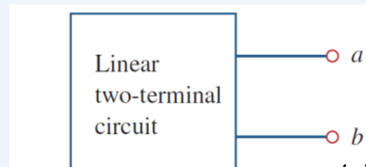
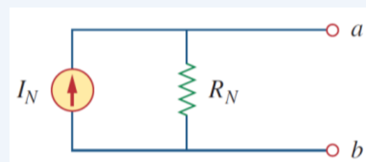
4.6 Norton's Theorem (1)

Norton's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N, where I_N is the short-circuit current through the terminals and R_N is the input or equivalent resistance at the terminals when the independent sources are turned off.



(a)



(b)

The circuit in (a) can be replaced by the one in (b)

We are mainly concerned with how to get R_N and I_N.

From what we know about source transformation, the Thevenin and Norton resistances are equal, so that

$$R_N = R_{Th}$$

Let's find Norton current I_N.

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4.6 Norton's Theorem (2)

We determine the short-circuit current flowing from terminal *a* to *b* in both circuits

The short-circuit current in (b) is I_N.

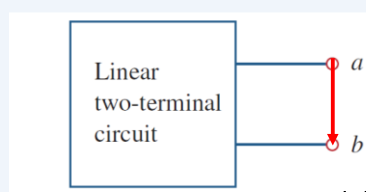
Since the two circuits are equivalent, then

$$I_N = I_{sc}$$

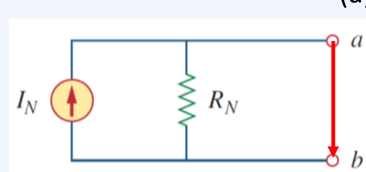
Observe the close relationship between Norton's and Thevenin's theorems

$$R_N = R_{Th} \qquad I_N = \frac{V_{Th}}{R_{Th}}$$

This is essentially source transformation. For this reason, source transformation is often called Thevenin-Norton transformation.



(a)



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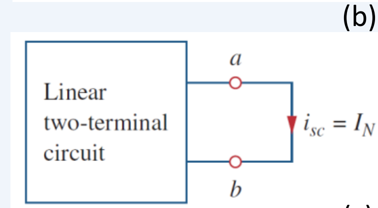

(c)

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4.6 Norton's Theorem (3)

To determine the Thevenin or Norton equivalent circuit requires that we find:

- The open-circuit voltage v_{oc} across terminals *a* and *b.*
- The short-circuit current i_{sc} at terminals *a* and *b.*
- The equivalent or input resistance R_{in} at terminals *a* and *b* when all independent sources are turned off.

$$\boldsymbol{V_{Th} = v_{oc}}$$

$$\boldsymbol{I_N = i_{sc}}$$

$$\boldsymbol{R_{Th} = \frac{v_{oc}}{i_{sc}} = R_N}$$

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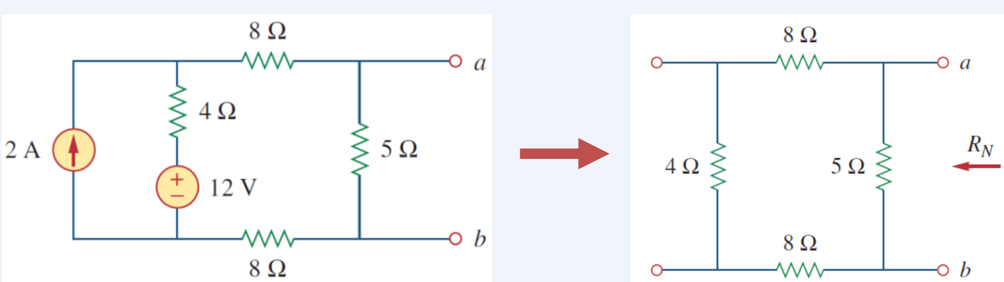
Example 4.11 (1) **Find the Norton equivalent circuit at terminals *a-b*.**

To find R_N Set the independent sources equal to zero



$$R_N = 5||(8+4+8) = 5||20 = \frac{20 \times 5}{20+5} = 4\ \Omega$$

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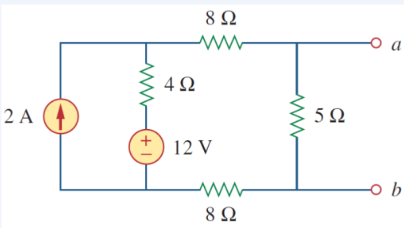
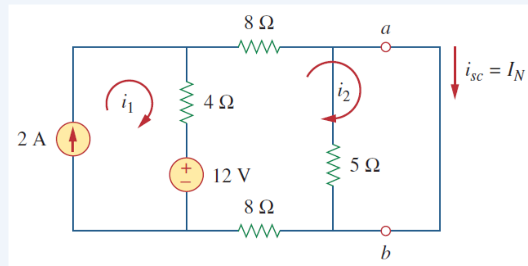
Example 4.11 (2)

Method 1: To find I_N, we short-circuit terminals *a* and *b*





Applying mesh analysis,

$$i_1 = 2\ A \quad (1)$$

$$20i_2 - 4i_1 - 10 = 0 \quad (2)$$

From eqns. (1) and (2)

$$\boldsymbol{i_2 = 1\ A = i_{sc} = I_N}$$

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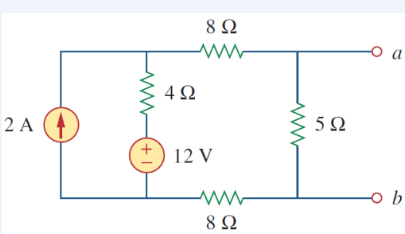
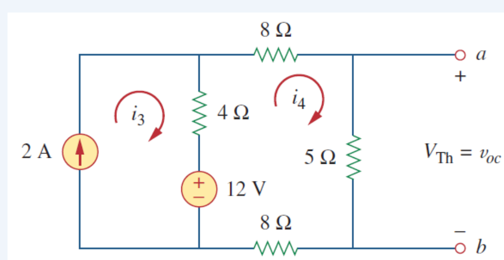
Example 4.11 (3)

Method 2: To find I_N, from V_{Th} and R_{Th}





Applying mesh analysis,

$$i_3 = 2\ A \quad (3)$$

$$25i_4 - 4i_3 - 12 = 0 \quad (4)$$

From eqns. (3) and (4)

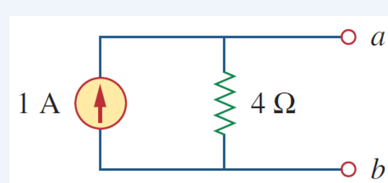
$$i_4 = 0.8\ A$$

$$v_{oc} = V_{Th} = 5i_4 = 4\ V$$

Hence,

$$\boldsymbol{I_N = \frac{V_{Th}}{R_{Th}}}$$

$$\boldsymbol{I_N = \frac{4}{4} = 1\ A}$$



Norton equivalent circuit

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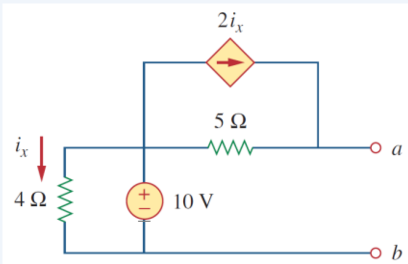
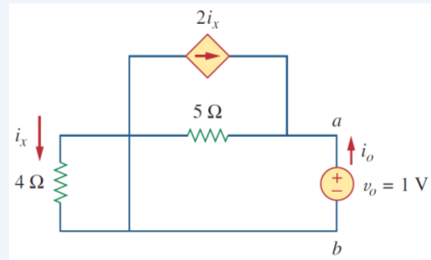
Example 4.12 (1)

Using Norton's theorem, find R_N and I_N of the circuit at a-b





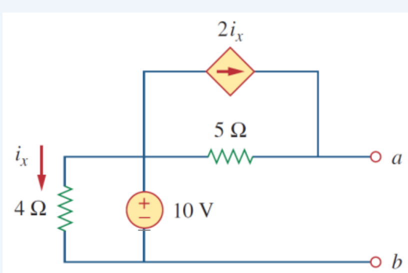
To find R_N Set the independent sources equal to zero, and connect a voltage source of v_o=1 V to the terminals. We ignore the 4 Ω resistor because it is short-circuited.

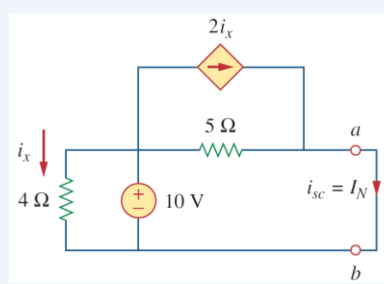
Also due to the short circuit, the 5 Ω resistor, the voltage source, and the dependent current source are all in parallel. Hence,

$$i_x = 0 \rightarrow i_o = \frac{1\,V}{5\,\Omega} = 0.2\,A$$

$$\therefore \boldsymbol{R_N} = \frac{\boldsymbol{v_o}}{\boldsymbol{i_o}} = \frac{\mathbf{1}}{\mathbf{0.2}} = \mathbf{5\,\Omega}$$

Example 4.12 (2)





To find I_N we short-circuit terminals *a* and *b* and find the current i_{sc}

The 4 Ω resistor, the 10-V voltage source, the 5 Ω resistor, and the dependent current source are all in parallel. Hence,

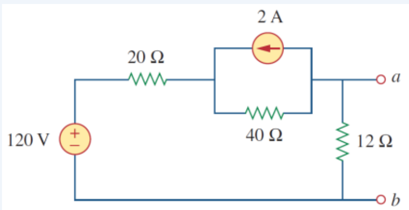
$$i_x = \frac{10}{4} = 2.5\,A$$

At node *a*, apply KCL

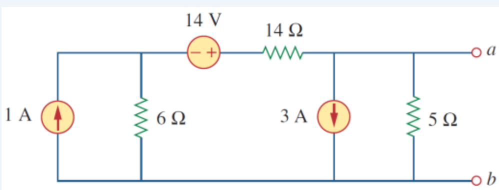
$$i_{sc} = \frac{10}{5} + 2i_x = 2 + 2(2.5) = 7\,A \rightarrow \boldsymbol{I_N = 7\,A}$$

Problems to Solve by yourself

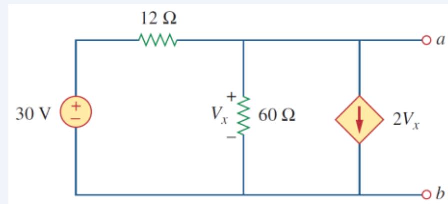
(1) Find the Norton equivalent with respect to terminals *a*-*b*.



(2) Find the Thevenin and Norton equivalents at terminals *a*-*b*



(3) Obtain the Thevenin and Norton equivalent



(4) Determine the Norton equivalent at terminals *a*-*b*